

## 8.0 Appendices

### Appendix A: Resource Equivalency Analysis

#### Background

There are two basic approaches to measuring the compensation for natural resources injuries. One is to focus on the demand side, the “consumer valuation approach”; the other is to focus on the supply side, the “replacement cost” approach. In the former, we seek to measure the monetary value that the public puts on the natural resources (i.e., how much the public demands the services of natural resources); in the latter, we seek to measure how much it costs to replace the natural resource services that the public loses as a result of the injury (i.e., how much it costs to supply natural resource services). See the Glossary for complete definitions of some of the terms used here.

**Figure 1:** Consumer Valuation versus Replacement Cost Approaches for Natural Resource Damage Calculation

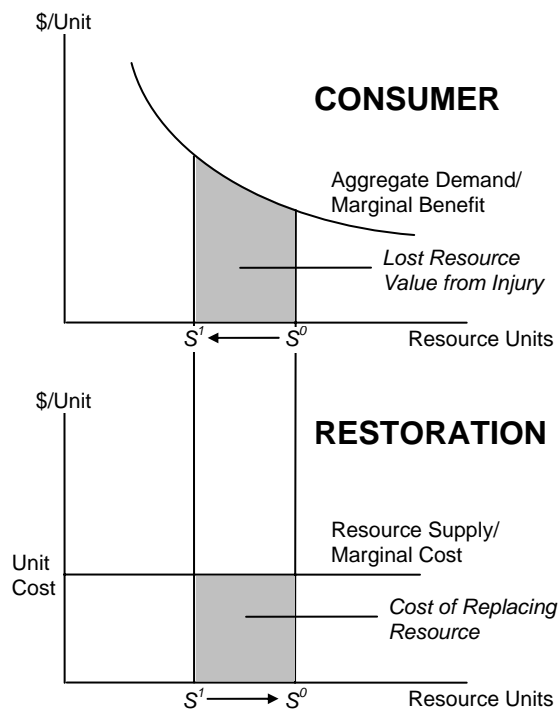


Figure 1 illustrates the difference between these two approaches. In both graphs, the supply of natural resources shifts from  $S^0$  to  $S^1$  as a result of an incident (e.g., oil spill, sediment discharge into a stream, illegal removal of vegetation). The shaded area in the top graph illustrates the dollar value of the resource loss as measured by the monetary payment that would make the public indifferent to the incident. For example, if each individual in a 30 million person society would need a \$.05 payment (on average) to make them indifferent to the resource loss, the shaded area in the top graph would equal \$1.5 million. Because the difficulty in observing market prices that reveal the level of cash payment that would compensate individuals for resource losses, the quantitative characteristics of the demand curve(s), and consequently the size of the shaded area in the

upper graph, are difficult to measure. Contingent Valuation (CV) and other types of analyses are designed to estimate this dollar value. These methodologies typically involve large surveys and can be costly.

The lower graph illustrates a replacement cost approach. Beyond noting that the injured resource has value, the actual extent to which the public values it is not directly considered. Instead, the determination of adequate compensation depends on the level of natural resource provision (versus monetary payments) that compensates society for what it has lost as a result of the incident. The cost of providing this compensation becomes the estimate of damages. Resource Equivalency Analysis (REA) is the primary methodology for conducting this type of measurement in natural resource damage assessment. It is depicted by a resource supply shift in the lower graph from  $S'$  back to  $S^0$ . The shaded area is the total monetary cost of funding the supply shift. For example, if 2 acres of wetland enhancement are estimated to compensate for an incident that temporarily reduced the service value of 1 acre of wetland habitat, the cost of performing 2 acres of wetland enhancement becomes the estimate of damages.

It is clear from Figure 1 that the public's valuation of the resource (the shaded area in the top graph) is not necessarily equal to the total replacement cost (the shaded area in the bottom graph). This is especially true when unique resources or rare species are involved, as the slope of the aggregate demand curve (top figure) may be much steeper due to resource scarcity. This would result in a much larger monetary payment being necessary to compensate the public. In such a case, the replacement cost approach of REA may result in damages far less than the losses as valued by the public. However, because it is easier and less costly to measure the total replacement cost than the total public value, REA has an advantage over other methods, especially for small to medium-sized incidents with minimal impact on rare species.

### **Resource Equivalency Analysis**

In this assessment, REA has been used to determining compensatory damages. This method is relatively inexpensive and relies primarily on biological information collected in the course of determining natural resource injuries caused by the spill. It is consistent with approaches recommended in the language of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the Oil Pollution Act of 1990 (OPA).

REA involves determining the amount of "natural resource services" that the affected resources would have provided had it not been injured, and it equates the quantity of lost services with those created by proposed compensatory restoration projects that would provide similar services. The unit of measure may be acre-years, stream feet-years, or some other metric. The size of the restoration project is scaled to the injury first; the cost of restoration is then calculated after the scaling has been done. The cost of restoring a comparable amount of resources to those lost or injured is the basis for the compensatory damages. In this sense, REA calculates the *replacement cost* of the lost years of natural resource services.

Future years are discounted at 3% per year, consistent with National Oceanic and Atmospheric Administration recommendations for natural resource damage assessments.

Discounting of future years is done based on the assumption that present services are more valuable than future services. When it comes to natural resources, the question of whether or not society should value the present more than future is a philosophical question (e.g., one can recall the “greenhouse effect” and the question of how much expense we should incur today to preserve the future). However, the question of how much society actually discounts the value of future natural resources is an empirical one. The 3% figure is currently the standard accepted discount rate for natural resource damage assessments.

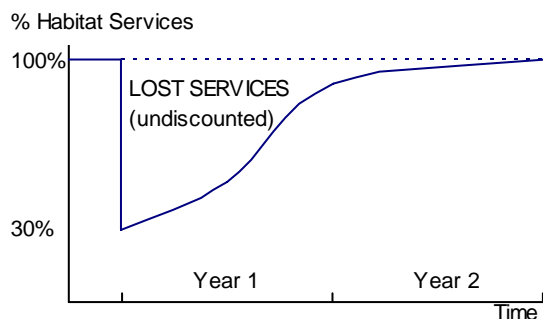
REA involves three steps: 1) the debit calculation, 2) the credit calculation, 3) the computation of the costs of restoration. These calculations may be done in a variety of ways, but the most common are to estimate the injury and the restoration benefits in terms of area years of habitat or animal years.

### Habitat Example

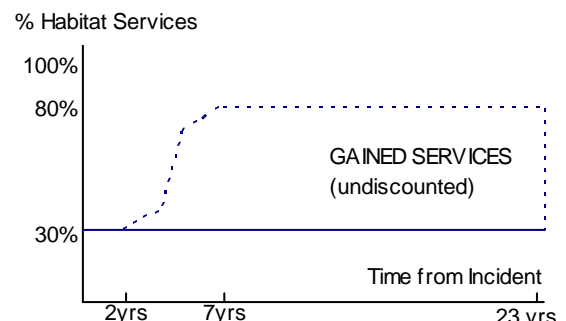
For example, suppose a 10-acre area is degraded due to an oil spill such that it supplies only 30% of its previous habitat services during the year following the incident. In the second year after the incident, the habitat begins to recover, supplying 90% of its baseline services. By the third year it is fully recovered. In this case, the lost acre years of habitat services would be  $70\% \times 10 \text{ acres} \times 1 \text{ year} + 10\% \times 10 \text{ acres} \times 1 \text{ year} = 8 \text{ acre years}$  of habitat services. Figure 2 illustrates this example by showing the recovery path of the habitat over time.

As stated above, future years are discounted at a 3% rate, thus the injuries in the second year count a little less. Incorporating this, 7.97 acre years of habitat services were lost. This difference appears minimal here, but becomes significant (due to compounding) if injuries persist many years into the future.

The credit calculation focuses on the gain in habitat services that result from a restoration project. Creating acre years of habitat services is a function of both area and time. Hypothetically, compensation could involve taking 7.97 acres of land with no habitat value (e.g., a parking lot) and turning it into productive habitat for 1 year. Alternatively, we could achieve compensation by creating 1 acre for 7.97 years. In reality, most restoration projects involve taking previously degraded habitat (at another nearby location) and restoring it over a number of years, and maintaining it into the future.



**FIGURE 2:** Biological Injury and Recovery



**FIGURE 3:** Restoration Trajectory/Credit

Suppose the restoration project improves the quality of a nearby degraded area, so that, if it previously provided only 30% of potential services, it would provide 80% of potential habitat services after restoration. Also suppose the project begins two years after the incident and it takes an additional 5 years for the 80% level to be achieved. Figure 3 provides an illustration of this restoration trajectory. In our hypothetical example, the project is expected to have a lifespan of 20 years. Note that, with future years discounted, the 20th year of the project (22-23 years after the incident) counts little; years after that are effectively completely discounted due to uncertainty regarding the future.

Mathematically, we seek to restore an area that will provide 7.97 acre years of services over the discounted 20-year phased-in life span of the restoration project. In this example, that would be an area of about 1.3 acres. That is to say, restoration of 1.3 acres for 20 years would compensate the public for the 7.96 lost acre years of habitat services due to the spill. Visually, the area identified in Figure 3 (multiplied by the affected acres and calculated to measure the present discounted value) should equal the area identified in Figure 4 (again, multiplied by the acres targeted for restoration and calculated to measure the present discounted value, thus discounting future years).

The percentage of habitat services lost (or gained, in the case of the restoration project) may be measured in a variety of ways. For our hypothetical oil spill case, three examples might include (1) the use of a habitat-wide evaluation index, (2) the use of one or more surrogate species, or (3) the use of an estimate based on the degree of oiling. Care must be taken when using a surrogate species to represent the entire affected habitat. Ideally, this surrogate is the population of one or more species that is immobile (that is, the animals do not move easily in and out of the affected area) and that has significant forward and/or backward ecological links to other species in the affected ecosystem. For example, the population of red crossbills, a bird that feeds primarily on pine cone seeds and migrates erratically from year to year, would be a poor surrogate for measuring injuries to a streambed. The aquatic macroinvertebrate community within the stream, however, provides an ideal surrogate, as they play a key role in the streambed food chain. Likewise, on the restoration side, care must be taken when the project targets one or a few species rather than the entire habitat. Ideally, a project that seeks to restore the population of a key indicator species will also benefit the entire habitat and, thus, other species as well. Indeed, such projects typically focus directly on habitat improvements. However, it is important to verify that such a species-centered project is indeed benefiting the entire habitat.

### **Animal Example**

When the injury is primarily to individual animals rather than a complete habitat, the REA may focus on lost animal-years. For example, suppose an oil spill causes negligible injury to a body of water, but results in the death of 100 ducks. Using information about the life history of the ducks (e.g., annual survival rate, average life expectancy, average fledging rate, etc.), we can estimate the “lost duck years” due to the spill. On the credit side, we can examine restoration projects designed to create duck nesting habitat and scale the size of the project such that it creates as many duck years as were lost in the incident.

**Restoration Costs = Natural Resource Damages**

Once the proposed restoration projects are scaled such that they will provide services equal to those lost due to the incident, the cost of the projects can be calculated. Note that this is the first time dollar figures enter the REA process. Until now, all the calculations of the “equivalency” have been in terms of years of resource services. The cost of the restoration projects is the compensatory damage of the incident.

Prepared by:

Steve Hampton, Ph.D.  
Resource Economist  
California Department of Fish and Game  
(916) 323-4724  
shampton@ospr.dfg.ca.gov

Matthew Zafonte, Ph.D.  
Resource Economist  
California Department of Fish and Game  
(916) 323-0635  
mzafonte@ospr.dfg.ca.gov

Revision Date: January 14, 2003

For another explanation of the REA methodology (in its more specific form for habitats), see “Habitat Equivalency Analysis: An Overview”, prepared by NOAA. Copies of this document are available at <http://www.darp.noaa.gov/library/pdf/heaoverv.pdf>.

## **GLOSSARY**

### **Aggregate demand**

the demand of all consumers combined; e.g., if there are 20,000 people in a town and each person demands two pieces of bread each day, the aggregate demand is 40,000 pieces of bread per day.

### **Compensatory restoration**

a restoration project which seeks to compensate the public for temporal or permanent injuries to natural resources; e.g., if a marsh is injured by an oil spill and recovers slowly over ten years, a compensatory project (which may be off site) seeks to compensate the public for the ten years of diminished natural resources.

### **Discount rate**

the rate at which the future is discounted, i.e., the rate at which the future does not count as much as the present; e.g., a dollar a year from now is worth less than a dollar today; if the bank offers a 3% rate, whereby \$1.00 becomes \$1.03 in one year, the future was discounted at 3%.

### **Primary restoration**

a restoration project which seeks to help an injured area recover more quickly from an injury; e.g., if a marsh is injured by an oil spill and would recover slowly over ten years if left alone, a primary restoration project might seek to speed the recovery time of the marsh and achieve full recovery after five years.

### **Replacement cost**

the cost of replacing that which was lost; e.g., if fifty acre-years of habitat services were lost due to an oil spill, the cost of creating fifty acre-years of similar habitat services would be the replacement cost.

## Appendix B: Bird Mortality Summary

### ESTIMATED MORTALITY BY SPECIES AND SPILL EVENT

Species/Groups	Winter 1990-91	Chronic 1993-1997	Winter 1997-98	Chronic 1998-2001	2001 - 2003	TOTAL
Waterfowl	7	1	835	2	17	862
Loons	129	2	838	13	326	1,308
Grebes	327	5	2,906	10	867	4,115
Procellarids	6	5	4,749	19	15	4,794
Brown Pelicans	22	0	198	2	56	278
Cormorants	209	1	711	10	529	1,460
Gulls	317	5	1,256	9	801	2,388
Snowy Plovers	2	0	23	0	5	30
Phalaropes	18	0	1,490	0	46	1,554
Other Shorebirds	12	2	0	0	31	45
Common Murre	2,348	37	23,300	64	6,159	31,955
Marbled Murrelet	4	0	32	0	9	45
Ancient Murrelet	42	0	281	0	105	428
Cassin's Auklet	31	0	1,395	5	78	1,509
Rhinoceros Auklet	59	1	379	5	149	593
Other Alcids	5	1	212	2	13	233
Land Birds	1	0	107	2	3	113
Other / Unknown	1	0	112	2	3	118
<b>TOTAL</b>	<b>3,537</b>	<b>60</b>	<b>38,682</b>	<b>143</b>	<b>9,205</b>	<b>51,719</b>

These figures include the totals estimated by the Beached Bird Model and other methods (for Snowy Plover and Marbled Murrelet), as described in Section 4.2.1.1. Additionally, 47 Common Murres were estimated killed in the winter of 1992-1993, based on observations from the Farallon Islands. This is not included in the table but is incorporated into the total mortality for murres shown in the table. As discussed in Section 4.2.1.1, 75% of the rehabbed and released Common Murres and Western Grebes were added as well. This increases the estimated dead for those species by 1.4% and 1.6% respectively.

## Appendix C: Methods for Calculating Lost Bird-Years

Lost bird-years were calculated several different ways, depending upon the species. Theoretically, lost bird-years are the difference between two different population trajectories: without the spills (baseline) and with the spills (injured). Without restoration, the two trajectories only converge (i.e. the injured population only recovers to baseline levels) if there is a natural compensating mechanism dependent upon population size (at least at the local, or colony, level). Thus, the calculation of lost bird-years must be consistent with a biological explanation of natural recovery over time (or lack thereof) (Zafonte and Hampton 2005).

For most bird species, the Single-Generation Stepwise Replacement Model was used to calculate lost bird-years. This approach is described below. For the Ashy Storm-Petrel, Common Murre, and Marbled Murrelet, a location-specific population model was used. Those will be described in the relevant appendices. For all bird-year calculations, a 3% discount rate is employed (discounted to the year 2006), consistent with common practice in natural resource damage assessments (e.g., see NOAA 1999).

The demographic parameters used in the bird REAs are drawn from one or more of the citations listed. In many instances, some parameters were adjusted (within the range of that reported in the literature) so that the overall population was calibrated appropriately to avoid implying unrealistic rates of increase or decrease.

### Single-Generation Stepwise Replacement Model

The single-generation stepwise replacement approach to calculating lost bird-years assumes that each year after a spill *the juvenile age class will be entirely replaced*. That is, despite the fact that some breeding adults have been killed, the population produces the same number of juveniles post-spill as it did pre-spill. Biologically, this could occur if the population was at carrying capacity with respect to breeding opportunities (perhaps limited by available nesting habitat or food base during the nesting season). The loss of some adults would open up room for other adults (i.e. “floaters”) to take over the vacant nesting opportunities and thus maintain the population’s annual production of juveniles. Thus, the youngest age class impacted by the spill will fully recover to its pre-spill level after the next breeding season. The second-year age class will fully recover two years after the spill, as the recovered first-year birds grow older. Likewise, the third-year age class will fully recover after three years, and so on. Mathematically, this is equal to calculating the number of years lost by the killed birds, based on the life expectancy of each age class. Details regarding the demographic parameters used to calculate lost bird years are presented in the relevant appendices for each species below.

This method roughly follows the same approach as used by Sperduto et al (1999, 2003) for calculating “direct loss” for birds with “extended” recovery times in the *North Cape* oil spill NRDA. Calculations are based upon the following assumptions:

***Assumption 1:*** Acute spill mortality is distributed proportionately across the various age classes of the injured population. In this case, Nevins and Carter’s

(2003) examination of Common Murres collected dead during the Point Reyes Tarball Incidents supports this assumption.

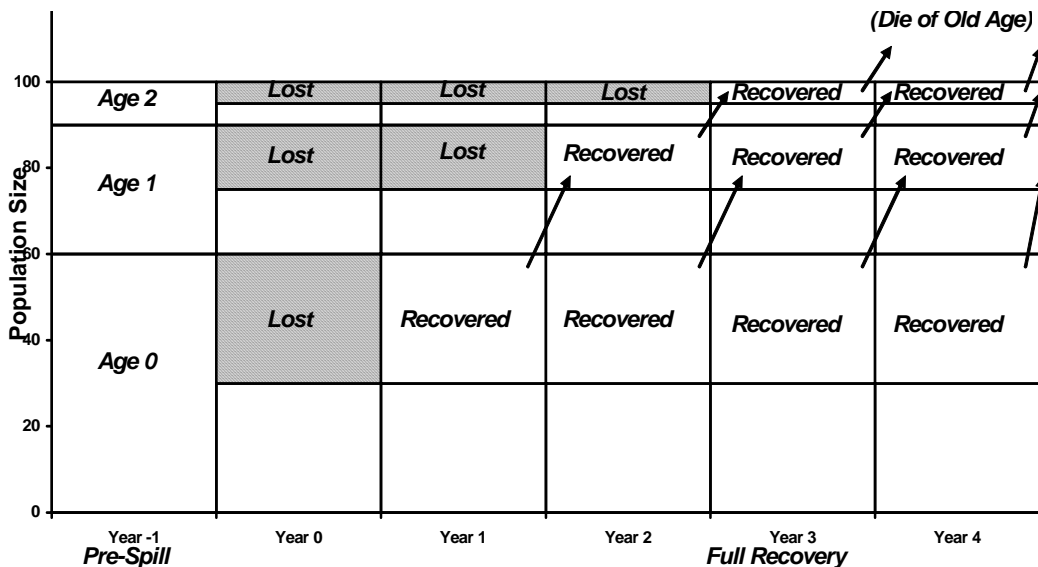
**Assumption 2:** Rates of juvenile and adult survivorship are constant before and after the spill.

**Assumption 3:** The pre-spill and fully recovered populations are roughly constant in size and stable in age-distribution, as determined by demographic characteristics of the species (specifically survivorship and fecundity).

**Assumption 4:** There is a maximum age beyond which no birds live.

**Assumption 5:** Surviving adult birds match the total reproductive output that the surviving and impacted birds would have had in the breeding seasons after the spill had the spill not occurred (i.e. the number of post-spill nests equals the number of baseline nests). This could occur because of non-breeding “floaters” in the area, reduced competition for high quality nesting sites, or decreased competition for foraging around the breeding area.

Figure 1 provides an example of how these assumptions combine to describe biological recovery in a hypothetical population with three one-year age classes. Year -1 depicts the population’s pre-spill conditions. Year 0 shows population numbers prior to the first full year after the spill. The shaded area is the number of each age class killed, which is distributed proportionately between age classes (Assumption 1). The arrows describe how the recovered birds advance through each age class.



In Year 1, the number of fledglings replaces the losses to the first age class (Assumption 5). The age classes from Year 0 all face annual mortality, with complete mortality for the third age class. This process continues in Year 2, with the recovered Age 0 juveniles from

Year 1 facing mortality and growing one year older to reach Age 1. In Year 3, there is full recovery. These calculations do not include impacts to future generations of birds (i.e., “indirect loss” as considered by Sperduto et al 1999, 2003).

## Appendix D: Loon/Kokechik Flats REA Details

### INJURY CALCULATION

Because breeding populations of the Pacific Loon, in particular, are thought to be limited by nest site availability (see Russell 2002), the Trustees applied the single-generation stepwise replacement approach to calculating lost bird-years as described in Appendix C. A lost bird-year multiplier (i.e. lost bird-years per bird killed) is first calculated, and then applied to the mortality events from the various years, discounted to 2006.

The North Cape REA (Spertudo et al 2003) calculates injuries to loons based upon Common Loon demographics. While data on Pacific Loons is limited, the demographic parameters likely do not vary meaningfully for this analysis. The following set of roughly stationary demographic parameters is based upon their analysis:

- *Age of First Breeding*: 5 Years Old
- *Female Offspring per Female (Annual)*: 0.27 (fecundity = 0.54)
- *Survivorship (From fledge to one year of age)*: 76%
- *Survivorship (Age 1+)*: 88.5%
- *Maximum Age*: 24 Years Old

The only difference between these parameters and those used by Sperduto et al (2003) is that annual survivorship beyond the first year has been increased 0.5%. This adjusts the implied loon life history to maintain an approximately constant population size. These parameters are consistent with data from studies summarized in McIntyre and Barr (1997) (for Common Loons), Barr et al (2000) (for Red-throated Loons), and Russell (2002) (for Pacific Loons). The result is that the bird-year multiplier is **6.29**.

This multiplier is then applied to the various mortality events, discounted to 2006.

<b>Spill Event</b>	<b>Estimated Mortality</b>	<b>Discounted Lost Bird-Years</b>
winter 1990-91	129	1,265
chronic 1993-97	2	17
winter 1997-98	838	6,682
chronic 1998-2001	13	95
2001-2003	326	2,242
<b>TOTAL</b>	<b>1,308</b>	<b>10,301</b>

Total discounted lost bird-years for loons: **10,301**.

### CREDIT CALCULATION (projected restoration benefits)

Based on aerial surveys of Pacific and Red-throated Loons at Kokechik Flats, the Trustees estimated that the project will benefit approximately 360 loon nests. Benefits per nest, in terms of increased productivity (or increased nest density) are difficult to estimate, as no data exists from this area. In Sperduto et al (2003), a project in New England to protect loon nests from disturbance was assumed to generate an additional 0.50 fledglings per nest, or almost triple fecundity (from 0.27 to 0.77). This equates to some of the highest productivity estimates (McIntyre and Barr 1997). The Trustees

consider that level of gains as an upper bound, and believe that a figure approximately half of that (i.e. an increase of 0.25 fledglings per nest) would be more realistic. The REA restoration benefits offset the injury when the project lasts 10 years and the benefits are 0.32 fledglings per nest. The Trustees believe this is a reasonable estimate. Even though the project only provides funding for 10 years, it is anticipated that, even if enforcement were to cease entirely, residual benefits via public education would provide benefits (at a declining rate) for an additional 15 years. This is incorporated into the credit calculations.

<b>Year</b>	<b>Protected Nests</b>	<b>Increased Fledges</b>	<b>Increased Bird-Years</b>	<b>Discounted to 2006</b>
2007	360	115	703	703
2008	360	115	703	683
2009	360	115	703	663
2010	360	115	703	644
2011	360	115	703	625
2012	360	115	703	607
2013	360	115	703	589
2014	360	115	703	572
2015	360	115	703	555
2016	360	115	703	539
2017	360	108	659	491
2018	360	101	615	444
2019	360	94	571	401
2020	360	86	527	359
2021	360	79	483	320
2022	360	72	439	282
2023	360	65	396	246
2024	360	58	352	213
2025	360	50	308	181
2026	360	43	264	150
2027	360	36	220	122
2028	360	29	176	94
2029	360	22	132	69
2030	360	14	88	45
2031	360	7	44	22
		Based on increase of 0.32 fledges per nest.	Based on 6.104 bird-years per fledge (life expectancy of a fledge)	Discounted at 3% per year
<b>Total:</b>				<b>9,616</b>

This project, protecting 360 nests for 10 years, compensates for the lost bird-years. Given the uncertainties in estimating project benefits, the Trustees consider this sufficient to compensate for the injuries. This project will simultaneously benefit thousands of phalarope and waterfowl nests, providing sufficient restoration for those species as well.

## Appendix E: Grebe/Colony Protection REA Details

### INJURY CALCULATION

Because breeding populations of the Western Grebe, in particular, may be limited by suitable nest colony sites, the Trustees applied the single-generation stepwise replacement approach to calculating lost bird-years as described in Appendix C. A lost bird-year multiplier (i.e. lost bird-years per bird killed) is first calculated, and then applied to the mortality events from the various years, discounted to 2006.

Data on Western Grebes is limited. Storer and Nuechterlein (1992) assume that most birds breed in their first year. Data from Clear Lake suggests that, in good years without nest colony disturbance, productivity is approximately 1.0 fledges/nest (D. Anderson, pers. comm.) (or 0.5 female offspring per female). The following set of demographic parameters imply an approximately constant population size:

- *Age of First Breeding*: 1 Year Old
- *Female Offspring per Female (Annual)*: 0.50 (fecundity = 1.00)
- *Survivorship (From fledge to one year of age)*: 60%
- *Survivorship (Age 1+)*: 70%
- *Maximum Age*: 20 Years Old

These parameters are consistent with data from information summarized in Storer and Nuechterlein (1992). The result is that the bird-year multiplier is **3.01**.

This multiplier is then applied to the various mortality events, discounted to 2006.

<b>Spill Event</b>	<b>Estimated Mortality</b>	<b>Discounted Lost Bird-Years</b>
winter 1990-91	327	1,533
chronic 1993-97	5	21
winter 1997-98	2,906	11,081
chronic 1998-2001	10	35
2001-2003	867	2,852
<b>TOTAL</b>	<b>4,115</b>	<b>15,521</b>

Total discounted lost bird-years for grebes: **15,521**.

### CREDIT CALCULATION (projected restoration benefits)

For project scaling, the Trustees focused on one of the targeted lakes, Clear Lake, where data is available. The project will benefit approximately 940 grebe nests at Clear Lake. Benefits per nest may be calculated using data collected by Dan Anderson of UC Davis. In 13 years of surveys, Anderson noted that 7 years featured good production, with an average of 1.0 fledges/nest. The other 6 years were marred by disturbance events, in which nest productivity plummeted, averaging only 0.2 fledges/nest. This equates to an overall average of 0.63 fledges/nest. Assuming the project is 80% successful in eliminating these disturbance events and maintaining annual average productivity at 0.5 fledges per nest, the benefits per nest from the project will be 0.30 fledges/nest.

<b>Year</b>	<b>Protected Nests</b>	<b>Increased Fledges</b>	<b>Increased Bird-Years</b>	<b>Discounted to 2006</b>
2007	940	278	782	782
2008	940	278	782	759
2009	940	278	782	737
2010	940	278	782	716
2011	940	278	782	695
2012	940	278	782	675
2013	940	278	782	655
2014	940	278	782	636
2015	940	278	782	618
2016	940	278	782	600
		Based on increase of 0.30 fledges per nest.	Based on 2.817 bird-years per fledge (life expectancy of a fledge)	Discounted at 3% per year
<b>Total:</b>				<b>6,873</b>

This project, protecting nests for 10 years, compensates for approximately half of the lost bird-years. The Trustees propose two similar projects: a 10-year project focused on Clear Lake and a 10-year project focused on other lakes.

## Appendix F: Procellarid/Farallon Islands REA Details

### INJURY CALCULATION

For lost bird-year calculations, Procellarids were divided into fulmars and shearwaters in one group, and storm-petrels in another group. Lost bird-years were calculated separately for each group.

For fulmars and shearwaters, the Trustees applied the single-generation stepwise replacement approach to calculating lost bird-years as described in Appendix C because breeding populations of most shearwaters appear limited by suitable nest colony sites, while fulmars appear limited by food availability (Hatch and Nettleship 1998). A lost bird-year multiplier (i.e. lost bird-years per bird killed) is first calculated, and then applied to the mortality events from the various years, discounted to 2006. The model relied on the demographic parameters of the Northern Fulmar.

The following parameters have been calibrated to imply a roughly constant population size:

- *Age of First Breeding: 5 Years Old*
- *Female Offspring per Female (Age 5): 0.013*
- *Female Offspring per Female (Age 6): 0.026*
- *Female Offspring per Female (Age 7): 0.039*
- *Female Offspring per Female (Age 8): 0.053*
- *Female Offspring per Female (Age 9): 0.066*
- *Female Offspring per Female (Age 10): 0.079*
- *Female Offspring per Female (Age 11): 0.092*
- *Female Offspring per Female (Age 12): 0.105*
- *Female Offspring per Female (Age 13): 0.118*
- *Female Offspring per Female (Age 14): 0.131*
- *Female Offspring per Female (Age 15): 0.144*
- *Female Offspring per Female (Age 16): 0.158*
- *Female Offspring per Female (Age 17): 0.171*
- *Female Offspring per Female (Age 18): 0.184*
- *Female Offspring per Female (Age 19): 0.197*
- *Female Offspring per Female (Age 20+): 0.21*
- *Annual Survivorship (Age 69-70): 6.9%*
- *Annual Survivorship (Age 68-69): 16.9%*
- *Annual Survivorship (Age 67-68): 26.9%*
- *Annual Survivorship (Age 66-67): 36.9%*
- *Annual Survivorship (Age 65-66): 46.9%*
- *Annual Survivorship (Age 64-65): 56.9%*
- *Annual Survivorship (Age 63-64): 66.9%*
- *Annual Survivorship (Age 62-63): 76.9%*
- *Annual Survivorship (Age 61-62): 86.9%*
- *Annual Survivorship (Age 5-6 to 60-61): 96.9%*
- *Annual Survivorship (Age 4-5): 89.6%*
- *Annual Survivorship (Age 3-4): 82.4%*

- *Annual Survivorship (Age 2-3): 75.1%*
- *Annual Survivorship (Age 1-2): 67.9%*
- *Survivorship (From fledge to one year of age): 60.6%*
- *Maximum Age: 70 Years*

To calibrate the model, we assumed that the survivorship from Ages 0-1 to 4-5 increased linearly each year such that 96.9% adult survivorship was achieved at Age 5-6. We then calibrated Age 0-1 survivorship so that the sequence was consistent with a population maintaining a constant population size. The result is that the bird-year multiplier is **12.70**.

This multiplier is then applied to the various mortality events, discounted to 2006.

<b>Spill Event</b>	<b>Estimated Mortality</b>	<b>Discounted Lost Bird-Years</b>
winter 1990-91	6	119
chronic 1993-97	5	88
winter 1997-98	4,749	76,402
chronic 1998-2001	19	280
2001-2003	15	208
<b>TOTAL</b>	<b>4,794</b>	<b>77,096</b>

Total discounted lost bird-years for Procellarids: **77,096**.

#### CREDIT CALCULATION (projected restoration benefits)

For project scaling, the Trustees focused on potential increases in the Ashy Storm-Petrel population breeding at the Farallon Islands, using a species and location-specific population model. The Ashy Storm-Petrel model relied on demographic parameters estimated from data collected at the Farallon Islands. These islands are home to over half of the world's population of the species, almost certainly the source location for the impacted birds, and the location of the restoration project. The sources of the data are Sydeman et al (1998) and Nur et al (1999). The parameters have been calibrated so that the population falls from 6,461 birds in 1972 to approximately 4,284 birds in 1992, consistent with estimates from Sydeman et al (1992).

- *Age of First Breeding: 5 Years Old*
- *Female Offspring per Female: 0.338 (fecundity = 0.676)*
- *Annual Survivorship (Age 3-4+): 88%*
- *Annual Survivorship (Age 2-3): 85%*
- *Annual Survivorship (Age 1-2): 70%*
- *Survivorship (From fledge to one year of age): 60%*
- *Maximum Age: 40 Years*

The restoration project will eradicate non-native mice from the islands. This, in turn, will affect productivity, by ending mouse predation of eggs and chicks, and the annual survival rate of adults, by decreasing predation by Burrowing Owls. The project will impact those parameters in these ways:

- *Female Offspring per Female: increases 10% to 0.371* (based on Ainley and Boekelhide 1990)
- *Annual Survivorship (Age 4-5+): increases from 88.0% to 90.8%* (this would imply that current Burrowing Owl predation is approximately 50 birds per year, given the Ashy Storm-Petrel breeding population of about 1,500 birds on the Farallon Islands).

These changes would stop the current population decline and cause the population to increase slowly (at approximately 1% annually). The model assumed project benefits would begin in 2008 and continue through 2150. The assumption of such long-term benefits is based upon the Trustees' confidence that the islands will remain free of introduced species through the oversight of the Farallon NWR.

The model calculates that the project will generate **74,024** bird-years for Procellarids, thus providing compensation for this species group.

## **Appendix G: Pelican, Cormorant, and Cassin's Auklet/Baja California Islands REA Details**

### **INJURY CALCULATION**

Because the pelicans and cormorants breeding along the Pacific coast of Baja California, where the restoration actions will take place, appear to be limited by suitable disturbance-free nest sites, the Trustees applied the single-generation stepwise replacement approach to calculating lost bird-years as described in Appendix C. This provides a rather conservative estimate, as there is considerable speculation that most sub-populations of pelicans and cormorants are limited by density-*independent* events such as food supply induced by oceanographic events (Shields 2002; D. Anderson, pers. comm., Wallace and Wallace 1998). In such situations, it is most correct to use the injury-into-perpetuity approach when calculating lost bird-years (Zafonte and Hampton 2005), which would have generated nearly five times as many lost bird-years. All losses were discounted to 2006.

For Cassin's Auklets, the Trustees also applied the single-generation stepwise replacement approach because breeding populations appear limited by suitable nest sites (Manuwal and Thoresen 1993). For example, Cassin's Auklets studied at the Farallon Islands are believed to have substantial numbers of non-breeding floaters, consistent with limitations on nest sites.

Estimates of annual productivity (fledges/pair) for cormorants and auklets was based upon 32-year means from data collected for Brandt's Cormorants and Cassin's Auklets at the Farallon Islands (Warzybok et al 2003). Annual productivity for pelicans is based upon Anderson et al (1982). For Brown Pelican data, we relied upon Williams and Joanen (1974) and Anderson et al (1996). For cormorants, we relied upon Wallace and Wallace (1998) and Hatch and Weseloh (1999). For Cassin's Auklets, little data exists on annual survivorship. We used known information on age of first breeding and a long-term mean on annual productivity from the Farallon Islands (Warzybok et al 2003). We then calibrated annual survival based upon other alcids and subject to the constraint that the population be constant.

### **Brown Pelicans**

- *Age of First Breeding*: 3 Years Old
- *Female Offspring per Female*: 0.33 (fecundity = 0.66)
- *Annual Survivorship (Age 3-4+)*: 88%
- *Annual Survivorship (Age 2-3)*: 80%
- *Annual Survivorship (Age 1-2)*: 72%
- *Survivorship (From fledge to one year of age)*: 64%
- *Maximum Age*: 34 Years

### **Cormorants (based on Brandt's and Double-crested Cormorant)**

- *Age of First Breeding*: 4 Years Old (plus 50% of 3 year-olds)
- *Female Offspring per Female*: 0.725 (fecundity = 1.45)
- *Annual Survivorship (Age 2-3+)*: 80%
- *Annual Survivorship (Age 1-2)*: 77%

- *Survivorship (From fledge to one year of age): 50%*
- *Maximum Age: 18 Years*

#### Cassin's Auklet

- *Age of First Breeding: 3 Years Old*
- *Female Offspring per Female: 0.36 (fecundity = 0.72)*
- *Annual Survivorship (Age 2-3+): 87.1%*
- *Annual Survivorship (Age 1-2): 70%*
- *Survivorship (From fledge to one year of age): 60%*
- *Maximum Age: 30 Years*

The results are that the bird-year multiplier is **5.97** for pelicans, **3.89** for cormorants, and **5.65** for Cassin's Auklets.

These multipliers were then applied to the various mortality events, discounted to 2006.

	Pelicans		Cormorants		Cassin's Auklets	
Spill Event	Estimated Mortality	Discounted Lost Bird-Years	Estimated Mortality	Discounted Lost Bird-Years	Estimated Mortality	Discounted Lost Bird-Years
winter 1990-91	22	205	209	1,267	31	273
chronic 1993-97	0	0	1	5	0	0
winter 1997-98	198	1,498	711	3,504	1,395	9,986
chronic 1998-2001	2	14	10	45	5	33
2001-2003	56	366	529	2,249	78	482
<b>TOTAL</b>	<b>278</b>	<b>2,083</b>	<b>1,460</b>	<b>7,070</b>	<b>1,509</b>	<b>10,773</b>

Total discounted lost bird-years for pelicans: **2,083**

Total discounted lost bird-years for cormorants: **7,070**

Total discounted lost bird-years for Cassin's Auklets: **10,773**

#### CREDIT CALCULATION (projected restoration benefits)

For project scaling, the Trustees focused on potential increases in populations at islands off the Pacific Coast of Baja California, Mexico (or prevention of decreases). By removing disturbance and opening up these islands as suitable nesting habitat, the project will protect existing populations from further disturbances and allow them to expand and take advantage of new nesting areas at these islands. The benefits will be for Brown Pelicans, cormorants, and Cassin's Auklets.

To calculate benefits, we assumed a population growth rate of at least 10 new nests per year for each species on each island, or colony growth of 3% per year, whichever was larger (or alternatively, the protection of 150 Cassin's Auklet nests/year at San Jeronimo and 1,000 nests/year at West San Benito that could otherwise be destroyed by human disturbance). If no birds were currently present on an island, but the project anticipated attraction of them, the starting point for the benefits trajectory was 10 nests beginning in 2008.

For each island, the number of increased nests, increased fledges, and increased bird-years from those fledges, was estimated for the duration of the 6-year project.

The results, as well as the current breeding populations with each island, are presented in the table below. Gained nests refer to the estimated number of new (or protected but otherwise lost) nests created as a result of the project. This number increases over time in cases where we anticipate population increases. Thus, “10 to 60” would mean 10 new nests at the beginning of the project, and 60 new nests at the end, after six years. The calculations assume that benefits begin in 2008, and all benefits are discounted to 2006.

ISLAND		PELICANS	CORMORANTS	CASSIN’S AUKLETS
San Martín	Current # nests	200	625	1,500
	Gained nests	10 to 60	19 to 121	45 to 291
San Jeronimo	Current # nests	0	20	5,000
	Gained nests	0	10 to 60	150
San Benito	Current # nests	200	142	35,000
	Gained nests	10 to 60	10 to 60	1,000
Natividad	Current # nests	55	800	10
	Gained nests	10 to 60	24 to 155	10 to 60
San Roque	Current # nests	10	100	10
	Gained nests	10 to 60	10 to 60	10 to 60
Asunción	Current # nests	0	10	10
	Gained nests	0	10 to 60	10 to 60
<b>TOTAL GAINED NESTS:</b>		<b>40 to 240</b>	<b>83 to 517</b>	<b>1,225 to 1,621</b>
FLEDGES PER NEST:		0.66	1.45	0.72
BIRD-YEARS PER FLEDGE:		4.36	3.09	4.13
<b>TOTAL GAINED BIRD-YEARS (discounted to 2006):</b>		<b>2,067</b>	<b>6,831</b>	<b>17,152</b>

The results show that the project will provide 99% of the compensation needed for injuries to pelicans, 97% of that required for cormorants, and 205% of that required for Cassin’s Auklets. Given the uncertainty associated with these estimates, the Trustees concluded that this project, by addressing the needs of several species simultaneously, was the most cost-effective way to provide the needed restoration.

## Appendix H: Snowy Plover/Point Reyes REA Details

### INJURY CALCULATION

Because breeding populations of the Snowy Plover are limited by the availability of suitable disturbance-free nest sites (Page et al 1995), the Trustees applied the single-generation stepwise replacement approach to calculating lost bird-years as described in Appendix C. A lost bird-year multiplier (i.e. lost bird-years per bird killed) is first calculated, and then applied to the mortality events from the various years, discounted to 2006.

Data regarding most demographic parameters are derived from Page et al (1995) and data from PRNS. Survivorship from fledging to age one is calibrated to a population decline of slightly more than 1% per year.

- *Age of First Breeding*: 1 Year Old
- *Female Offspring per Female (Annual)*: 0.50 (fecundity = 1.00)
- *Survivorship (From fledge to one year of age)*: 60%
- *Survivorship (Age 1+)*: 80%
- *Maximum Age*: 15 Years Old

The result is that the bird-year multiplier is **3.95**.

This multiplier is then applied to the various mortality events, discounted to 2006. Mortality by spill event was distributed proportionately according to total estimated bird impacts by spill event and is closely correlated to the number of observed oiled Snowy Plovers.

<b>Spill Event</b>	<b>Estimated Mortality</b>	<b>Discounted Lost Bird-Years</b>
winter 1990-91	2	12
chronic 1993-97	0	0
winter 1997-98	23	115
chronic 1998-2001	0	0
2001-2003	5	22
<b>TOTAL</b>	<b>30</b>	<b>150</b>

Total discounted lost bird-years for Snowy Plovers: **150**.

### CREDIT CALCULATION (projected restoration benefits)

The project has been scaled to 30 acres in size. Based on data from the pilot study, this will lead to the establishment of at least four nests, generating an equal number (1.0 fledges per female per year) of fledges each year. Project benefits ramp up over two years, the time to implement the project. Because the project budget does not fund on-going maintenance to control non-native vegetation, project benefits begin to ramp down after 8 years, assuming a modest rate of re-colonization by non-native vegetation (2 acres per year).

Year	Restored Acres	New Nests	Increased Fledges	Increased Bird-Years	Discounted to 2006
2007	15	2.0	2.0	7.1	6.9
2008	30	4.0	4.0	14.2	13.4
2009	30	4.0	4.0	14.2	13.0
2010	30	4.0	4.0	14.2	12.6
2011	30	4.0	4.0	14.2	12.2
2012	30	4.0	4.0	14.2	11.9
2013	30	4.0	4.0	14.2	11.5
2014	30	4.0	4.0	14.2	11.2
2015	28	3.7	3.7	13.3	10.2
2016	26	3.5	3.5	12.3	9.2
2017	24	3.2	3.2	11.4	8.2
2018	22	2.9	2.9	10.4	7.3
2019	20	2.7	2.7	9.5	6.4
2020	18	2.4	2.4	8.5	5.6
2021	16	2.1	2.1	7.6	4.9
2022	14	1.9	1.9	6.6	4.1
2023	12	1.6	1.6	5.7	3.4
2024	10	1.3	1.3	4.7	2.8
2025	8	1.1	1.1	3.8	2.2
2026	6	0.8	0.8	2.8	1.6
2027	4	0.5	0.5	1.9	1.0
2028	2	0.3	0.3	0.9	0.5
2029	0	0.0	0.0	0.0	0.0
		Based on 0.13 nests/acre from the pilot study.	Based on increase of 1.0 fledges per nest.	Based on 3.55 bird-years per fledge (life expectancy of a fledge)	Discounted at 3% per year
<b>Total:</b>					<b>160</b>

This project, restoring 30 acres of Snowy Plover nesting habitat, compensates for the lost bird-years.

## Appendix I: Common Murre REA Details

### INJURY CALCULATION

Lost bird-years were calculated using a local population model of the Common Murre. Because Common Murres are still recovering from historical declines, population growth appears to be linked to general oceanic conditions rather than density-dependent factors such as nest site availability (N. Nur, pers. comm.). The current central California population is approximately 250,000 breeding birds (G. McChesney, pers. comm.). Historically, there may have been well over a million (Carter et al 2001). Due to favorable oceanic conditions in recent years, the central California population has begun to recover and has grown at an average rate of over 5% per year (from 1990 to 2004 at the Farallon Islands). In good years, the population grows as much as 7-9% per year. In bad years, a fraction of the population attends the breeding colonies. Recovery to historical levels has been impacted and delayed by the spills. Nur et al (1997) estimated that chronic oil pollution (now largely attributed to the *Luckenbach*) may have lowered population growth rates by as much as 3% per year. The modeling here, using the mortality estimates described in Appendix B, show an average annual reduction in population growth rates of under 1% per year between 1990 and 2003.

The Trustees scaled restoration based upon a local population model that incorporated both “good years” (occurring 80% of the time) and “bad years” (20% of time). The model is based on the assumptions that, while no density dependent mechanism is currently operating in the population, reproductive output at high population levels is ultimately affected by: (1) an absolute limitation of the number of birds that breed in the region; (2) potential variability in nest sites both within and across colonies; and (3) possible food source limitations around the breeding areas (i.e., that might result in longer, more energetically intensive, food searches during breeding season). The underlying population model is similar to the approach used by Swartzman (1996) in his analysis of impacts to the Common Murre from the *Apex Houston* oil spill.<sup>1</sup>

Common Murre demographics were derived based on a various sources (Nur et al 1994; Swartzman 1996; Carter et al 2001; W. Sydeman, pers. com). The model was calibrated using historical breeding population estimates, estimated mortality from the various spill years, known oceanic conditions from the past (i.e., “good years” and “bad years”). The following set of demographic parameters reflects that calibration:

- *Female Offspring per Female in Pop. (Age 7+):* 0.40 (good year); 0.04 (bad year)
- *Female Offspring per Female in Pop. (Age 6):* 90% of fully mature (age 7+)
- *Female Offspring per Female in Pop. (Age 5):* 60% of fully mature (age 7+)
- *Female Offspring per Female in Pop. (Age 4):* 35% of fully mature (age 7+)

---

<sup>1</sup> The multiple breeding rocks within the spill area suggest the possibility that a “meta-population” model might better reflect the response to both the mortality events and restoration projects. We mostly focus on a single population model because: (1) we have insufficient information to specify immigration-emigration parameters between colonies inside the spill area; (2) the majority of birds are in a single colony (South Farallon Island complex) and the dominant portion of birds is in two closely proximate colonies (South and North Farallon Island complexes).

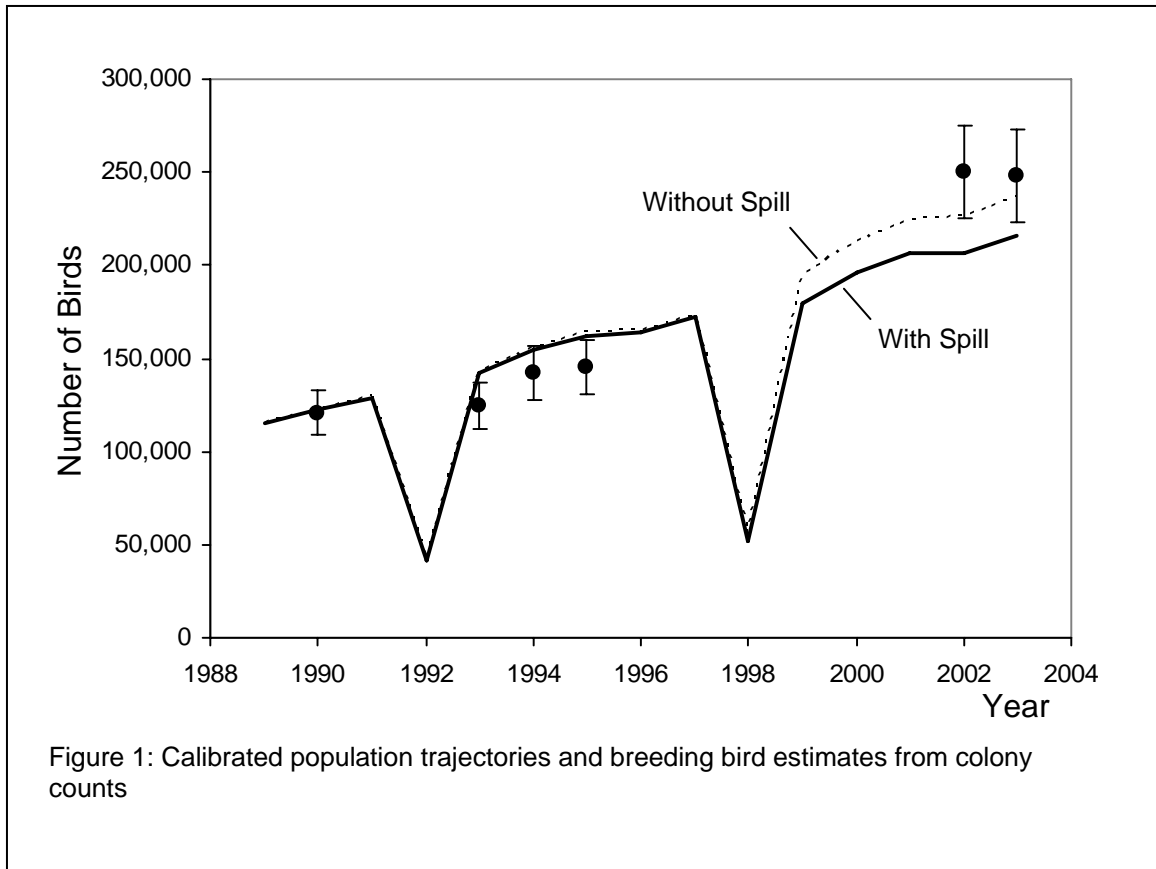
- *Proportion of Females Breeding (Age 4)*: 48% (good year); 15% (bad year)
- *Proportion of Females Breeding (Age 5)*: 71% (good year); 23% (bad year)
- *Proportion of Females Breeding (Age 6+)*: 95% (good year); 30% (bad year)
- *Survivorship (From fledge to one year of age)*: 60% (good year); 30% (bad year)
- *Annual Survivorship (Age 1-2)*: 83% (good year); 80% (bad year)
- *Annual Survivorship (Age 2-3)*: 90% (good year); 87% (bad year)
- *Annual Survivorship (Age 3+)*: 96% (good year); 92% (bad year)

For future losses and gains, the Trustees used “average conditions” to examine the population. Average was based upon the proportion-weighted geometric means of parameters from both good- and bad-years.<sup>2</sup> When approximating future population growth, the Trustees assume that there is a maximum of 1,000,000 breeding birds (per Carter et al 2001), that density dependence will begin to operate at 50% of this maximum, and that mature fledging success will decline linearly with breeding population size until it reaches the stationary value when there are 1,000,000 breeding birds in the population.

Figure 1 plots the combined good-year and bad-year growth rates against estimates of breeding birds based upon historic colony counts. The error bars around the estimates are 10% to reflect the 8-12% error in using a constant correction factor ( $k = 1.6$ ) to transform colony counts to breeding population size (Nur and Sydeman 2004). 1992 and 1998 are assumed to be “bad years” because of the 1992-93 and 1998-99 El Nino events. The solid line is the estimated trajectory that includes spill mortality. The model underestimates the 2002 and 2003 colony counts, which is reasonable as the 2002 and 2003 counts may include an uncharacteristically large number of non-breeding sub-adults that are a result of several sequential productive years (W. Sydeman, pers. comm.). The dashed line is the predicted population trajectory assuming that the estimated spill mortality did not occur. The injury is the area between the solid and dashed lines.

---

<sup>2</sup> A stochastic population model was compared with the “average population” model to ensure consistency of the deterministic approximation.



Spill mortality is described in the table below:

<b>Spill Event</b>	<b>Estimated Mortality</b>
Winter 1990-91	2,348
Winter 1992-93	47
Chronic 1993-1997	37
Winter 1997-98	23,300
Winter 2001-02	5,091
Winter 2002-03	1,068
Chronic 1998-2001	64
<b>TOTAL</b>	<b>31,955</b>

### CREDIT CALCULATION (projected restoration benefits)

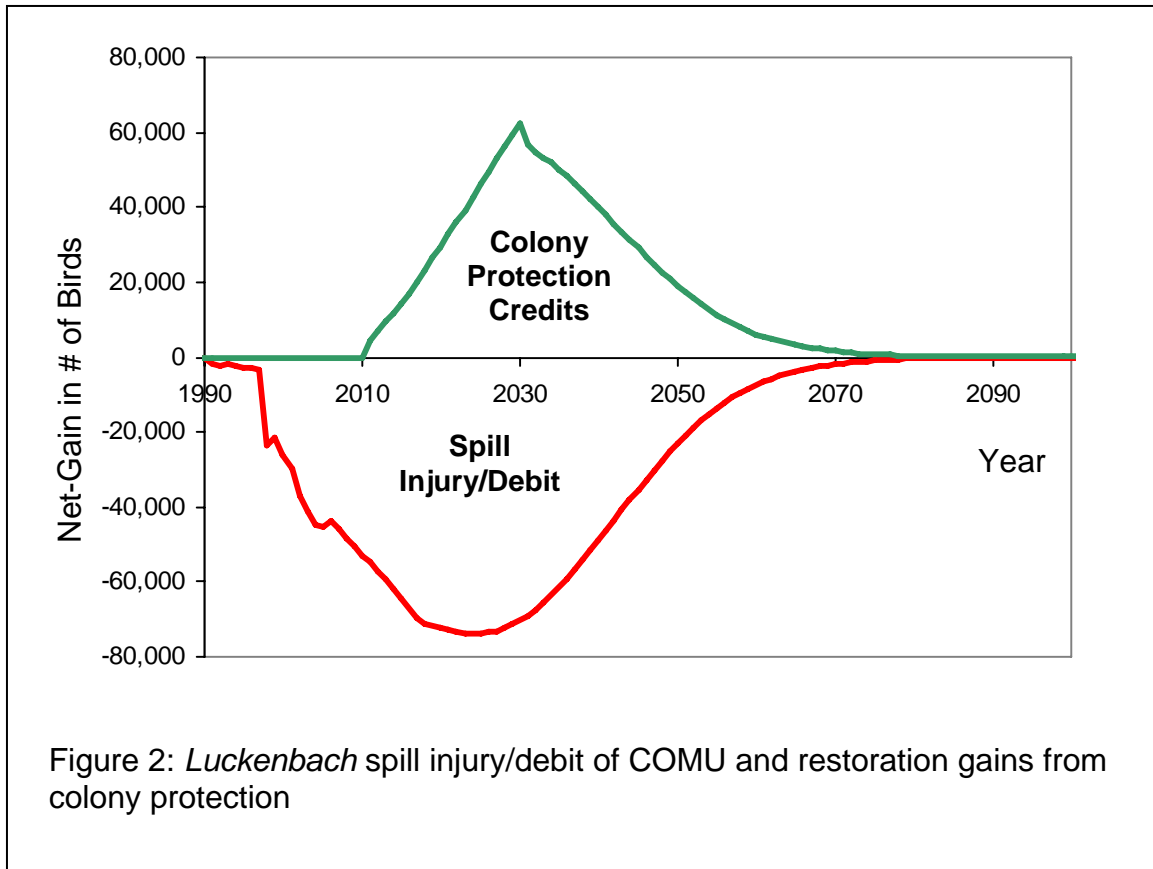
To address the injuries, the Trustees are proposing three restoration projects: 1) regional colony protection, 2) corvid management at Pt. Reyes, and 3) Reading Rock colony restoration.

#### *1. Colony Protection*

The seabird colony protection project, which seeks to reduce human disturbances at nesting colonies throughout the region, was examined at the same time as the injury using the same population model. This project will add to and extend an on-going project being implemented by the Command Trustee Council. Three population trajectories were examined:

- **Baseline:** a projection of the number of Common Murres in the spill area, including benefits of the initial colony protection program implemented by the *Command* Trustees (which increases nest success for the years 2006 to 2009).
- **Injury:** a projection of the number of murres in the central California population that incorporates both the spill mortality from the *Luckenbach* (and other local orphan spills) and the colony protection project implemented by the *Command* Trustees.
- **Restoration:** a projection of the number of murres in the central California population, given: (1) the various spill events; (2) colony protection from the *Command* Trustees; and (3) colony protection funded from a project that begins providing benefits to Common Murres in 2010 (once the *Command* project ceases).

Figure 2 illustrates the spill injuries and colony protection benefits using the trajectories. The injury depicted in Figure 2 is the difference between the Baseline and Injury trajectory (i.e., “How much did the public lose compared to Baseline?”). The restoration credit is the difference between the Restoration and Injury trajectories (i.e., “How much does the public gain now that the restoration project benefits the injured population?”). The modeling showed that a 20-year seabird colony protection project, which increases fecundity by 5%, compensates for approximately 38% of the spill injuries (in discounted bird-years).



## 2. Corvid Management

The project is based upon the observation that nest predation by corvids has resulted in lower nest success at Pt. Reyes than the overall average in the spill area (Parker et al 2000, Parker et al 2001, Knectel et al 2003). Since the corvid management option will only benefit the Pt. Reyes colony, we focus on increases in productivity at that site. The benefits are based upon the comparison of two population trajectories:

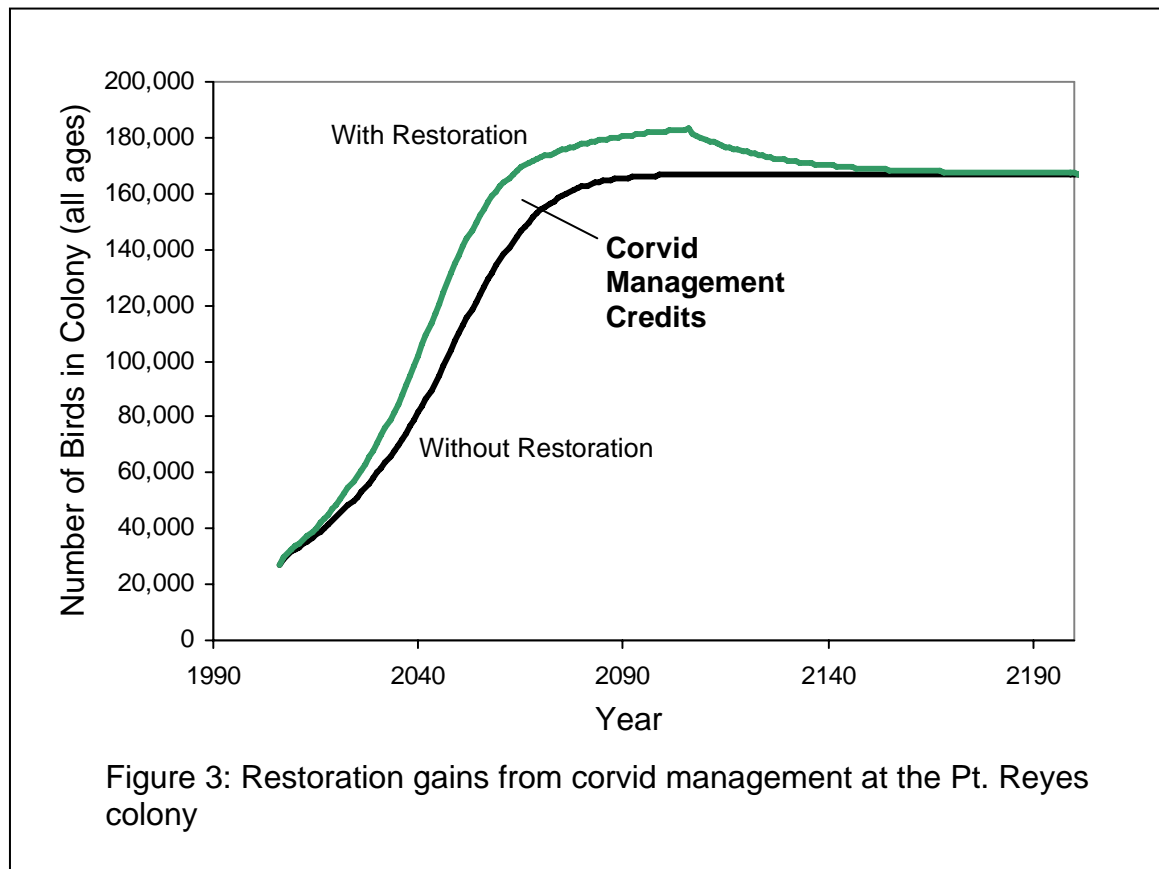
- **Baseline (without restoration):** Pt. Reyes Headlands murre population size over time given post-spill colony numbers and the positive impacts of the human disturbance colony protection project noted above.
- **Restoration:** This is the baseline condition with the increased nest success at Pt. Reyes Headlands that results from reducing corvid predation.

The gain from the corvid management project is the difference between these two trajectories.

Average nest success (i.e., fledges per nest) at study plots in the Pt. Reyes colony was approximately 81% of the nest success at plots at the Farallones over the 1999-2002 period (Parker et al 2000, Parker et al 2001, Knectel et al 2003, Worzybok et al 2003). For the purpose of quantifying restoration benefits, the Trustees assume that the

“baseline” nests at Pt. Reyes are 81% as successful as the current area-wide average. This nest success assumption calibrated to past changes in colony counts. The Trustees also assumed that the nests will be 90% successful as the area-wide average after the corvid management program is implemented. The Trustees do not credit the project with achieving a full 100% of the Farallones nest success because: (1) corvid management may not be 100% successful; and (2) other factors may also be contributing to a reduced nest success at the Pt. Reyes colony.

The underlying population model used to calculate corvid management benefits is similar to the one used to model the entire spill injury and colony protection benefits. The Trustees use the same density dependent mechanisms and same survivorship parameters. However, a limit of 100,000 birds is used instead of one million breeding birds, and the project is assumed to provide benefits for 100 years. This long duration assumes that PRNS will continue to manage its corvid populations. Figure 3 depicts the trajectories with and without the restoration project. The difference between them is the net-gain from this project, which compensates for approximately 21% of the injury.



### (3) Reading Rock Colony Restoration

Calculation of the restoration benefits of the Reading Rock murre colony restoration project is based upon the assumption that social attraction at Reading Rock would draw “not otherwise breeding” adults associated with other colonies in the region. The rate at

which social attraction resulted in new nests was quantified using data from recent restoration efforts at the Devil's Slide Rock, and assuming a 5% growth rate in nests beyond the available data (until a maximum of 1,800 nests are achieved). This is summarized in the following table:

<b>Year</b>	<b>Increased Nests</b>	<b>Increased Fledges</b>	<b>Increased Bird-Years</b>	<b>Discounted to 2006</b>
2008	0	0	0	0
2009	6	4	17	16
2010	9	6	26	23
2011	14	10	40	34
2012	70	51	199	167
2013	98	71	279	227
2014	115	83	327	258
2015	123	89	350	268
2016	109	79	310	231
2017	190	137	540	390
Continues to 2107	Continues at 5% annual growth until maximum at 1,800 nests.	Based on 0.722 fledges per nest.	Based on 3.94 bird-years per fledge (life expectancy of a fledge)	Discounted at 3% per year
<b>Total:</b>				<b>53,772</b>

Note: First seven years of nest numbers and fledges per nest based on data from Devil's Slide Rock Murre Re-colonization Project (McChesney et al 2004).

Estimates of gained bird-years per fledge are based upon demographic parameters that were calibrated to the roughly constant Common Murre population levels off the North Coast. A more detailed description of these parameters (and the scaling) can be found in Stuyvesant Trustee Council (2004).

Other funding sources are expected to contribute 48% of the funding to conduct the Reading Rock project. This leaves a 52% contribution available for funding via the *Luckenbach* claim. A project that contributes 52% of the funding would account for 52% of the gained bird-years (i.e., 27,962 bird-years discounted to 2006).

#### *Summary of Common Murre Project Scaling*

Altogether, these three projects address approximately 61% of the injury to Common Murres. Due to the size of the injury and the fact that several other projects benefiting Common Murres (associated with other oil spills) are already being implemented (e.g. see Command Trustee Council (2004), Stuyvesant Trustee Council (2004), and McChesney et al (2005)), the Trustees have not identified any additional projects at this time.

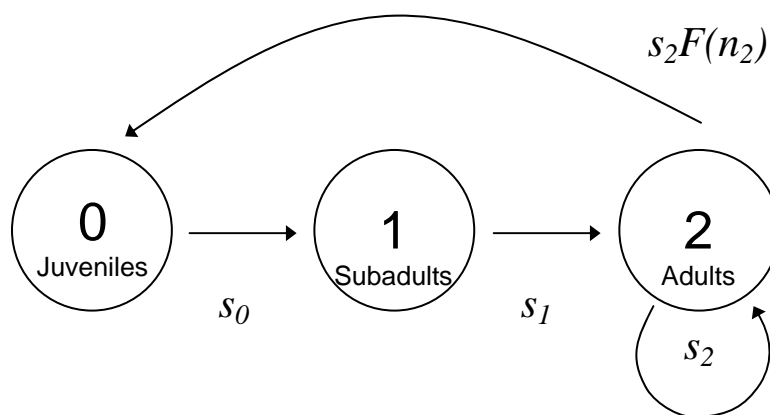
## Appendix J: Marbled Murrelet REA Details

### INJURY CALCULATION

The Trustees calculated the injury to Marbled Murrelets using a species-specific model incorporating data from the declining Santa Cruz Mountain population. First, the Trustees modeled both baseline and injured trajectories of the population. The injured trajectory started with the same initial population level as the baseline trajectory, but the birds were removed consistent with estimated spill mortality.

Spill Event	Estimated Mortality
winter 1990-91	4
chronic 1993-97	0
winter 1997-98	32
chronic 1998-2001	0
2001-2003	9
<b>TOTAL</b>	<b>45</b>

Both population trajectories relied on the following adaptation of the Beissinger (1995) model.



The parameters  $s_0$ ,  $s_1$ , and  $s_2$  are the survivorships for juveniles, subadults and adults, respectively. The term  $s_2 F(n_2)$  reflects the “post-breeding” census convention (i.e., bird-years are counted in the fall). This implies that adult murrelets ( $n_2$ ) must survive ( $s_2$ ) before they are able to attempt successful breeding ( $F(n_2)$ ). In the model, fecundity increases as the population becomes smaller. This reflects the possibility that, as a population declines, it will tend to decline faster in more marginal areas leaving the remaining birds in higher quality habitat. The estimate of lost bird-years is the difference between the two trajectories. The parameters are presented below.

### CREDIT CALCULATION (projected restoration benefits)

The Trustees are proposing two restoration projects to address the injury to Marbled Murrelets. Land acquisition would protect nests that would otherwise be subject to total loss through logging. The corvid management project in Santa Cruz Mountain

campgrounds would increase nest success by decreasing the predation of eggs and chicks by corvids. At present, nest success in the Santa Cruz Mountains is extremely low.

There is sufficient data regarding murrelet reproduction to scale the land acquisition project. Unfortunately, because murrelet nests are so difficult to monitor, there is little data regarding changes in nest success as a result of corvid management. The Trustees have conducted the scaling based upon the land acquisition project, assuming that, because it will be concurrent with the corvid management project, the nests to be protected by land acquisition will be “good nests” (i.e. they will produce enough fledglings to stabilize the population level and stop further declines). Thus, the implementation of the corvid management project justifies this critical assumption regarding nest success in the lands to be protected.

The land acquisition project is scaled based upon the number of good nests that must be protected in order to offset the injury. The number of acres that must be acquired is simply a function of average nest density. The benefit per protected nest is the difference between fecundity at the protected site (without logging) and what fecundity would be if the birds were forced to nest elsewhere (with logging). Because the corvid management project will be implemented simultaneously, we assume that: (a) with acquisition, nests are sufficiently productive to maintain population levels; and (b) without acquisition, the birds associated with these nests will reproduce at a lower fecundity after logging occurs.

The model was calibrated using population estimates (see McShane et al 2004), estimated mortality from the various spill years, and estimates of Marbled Murrelet demographic parameters (Beissinger 1995, Cam et al 2003, McShane et al 2004, Nur 1993). Because there is uncertainty with regard to several of the parameters, the Trustees conducted a Monte Carlo analysis that examined ranges of parameter inputs, subject to constraints for biological consistency (e.g., was consistent with “juvenile ratio” observations at-sea). 2,000 combinations of parameter inputs were explored. The potential parameter ranges for the main inputs were:

- *Annual Survivorship (Age 2+)*: 83-93%
- *Annual Survivorship (Age 1-2)*: 83-95% of Age 2+ Survivorship
- *Survivorship (From fledge to one year of age)*: 60-82% of Age 2+ Survivorship
- *Female Offspring per Female (Annual)*: Selected to be consistent with 5-10% annual population decline, given survivorship
- *Logging Time*: Between October 2010 and March 2011

Eliminating the first and last quartiles from the simulation results, the Monte Carlo analysis suggests that protecting 5.7 to 7.7 nests would compensate for the injury. Using an average of 20 acres per nest (Conroy et al 2002), 114 to 154 acres would need to be protected from logging.

## Appendix K: Ancient Murrelet/Queen Charlotte Islands REA Details

### INJURY CALCULATION

Because breeding populations of the Ancient Murrelet may be limited by suitable nest colony sites (Gaston 1994), the Trustees applied the single-generation stepwise replacement approach to calculating lost bird-years as described in Appendix C. A lost bird-year multiplier (i.e. lost bird-years per bird killed) is first calculated, and then applied to the mortality events from the various years, discounted to 2006.

The following set of demographic parameters implies an approximately constant population size:

- *Age of First Breeding*: 3 Year Old
- *Female Offspring per Female (Annual)*: 0.825
- *Survivorship (From fledge to one year of age)*: 59%
- *Annual Survivorship (Age 1-2)*: 62%
- *Survivorship (Age 1+)*: 77%
- *Maximum Age*: 20 Years Old

These parameters are consistent with data from information summarized in Gaston (1994). The result is that the bird-year multiplier is **3.48**.

This multiplier is then applied to the various mortality events, discounted to 2006.

<b>Spill Event</b>	<b>Estimated Mortality</b>	<b>Discounted Lost Bird-Years</b>
winter 1990-91	42	228
chronic 1993-97	0	0
winter 1997-98	281	1,240
chronic 1998-2001	0	0
2001-2003	105	400
<b>TOTAL</b>	<b>428</b>	<b>1,867</b>

Total discounted lost bird-years for Ancient Murrelets: **1,867**.

### CREDIT CALCULATION (projected restoration benefits)

For project scaling, the Trustees focused on potential benefits from rat eradication at Ellen Island and the Bischof Islands. Full compensation for the injury can be achieved if re-colonization from adjacent islands occurs at a rate of just 3 nests per year, beginning in the year 2010 and continuing through 2100. This calculation also assumes a 1% annual risk of rat reintroduction for the first 10 years, increasing by 1% in each of the following decades. This effectively incorporates uncertainty into the discount rate. The risk of rodent reintroduction is greater here than on the Farallones because the islands are difficult to monitor. The Farallones, in contrast, have full-time research staff and every boat landing can be monitored. Benefits per nest were assumed to be 1.65 fledges/nest, at the high end of the range reported by Gaston (1994). The table below presents these results.

<b>Year</b>	<b>New Nests</b>	<b>New Fledges</b>	<b>New Bird-Years</b>	<b>Discounted to 2006</b>
2007	0	0	0	0
2008	0	0	0	0
2009	0	0	0	0
2010	2	3	10	8
2011	4	7	19	16
2012	6	10	29	23
2013	8	13	39	29
2014	10	17	48	35
2015	12	20	58	41
2016	14	23	68	46
2017	16	26	77	50
2018	18	30	87	54
2019	20	33	97	51
2020	22	36	106	54
2021	24	40	116	56
2022	26	43	126	58
2023	28	46	136	59
2024	30	50	145	60
2025	32	53	155	61
2026	34	56	165	62
2027	36	59	174	63
2028	38	63	184	63
2029	40	66	194	51
2030	42	69	203	50
	Increases at 2 nests per year, continuing thru 2100.	Based on 1.65 fledges per nest.	Based on 2.93 bird-years per fledge (life expectancy of a fledge)	Discounted at 3% per year
<b>Total:</b>				<b>1,813</b>

Under these assumptions, this project compensates for the lost bird-years.

## Appendix L: Rhinoceros Auklet/Año Nuevo Island REA Details

### INJURY CALCULATION

For Rhinoceros Auklets, the Trustees applied the single-generation stepwise replacement approach because breeding populations appear limited by suitable nest sites (Gaston and Dechense 1996). A lost bird-year multiplier (i.e. lost bird-years per bird killed) is first calculated, and then applied to the mortality events from the various years, discounted to 2006.

Thayer et al (in prep) estimated age of first breeding, annual productivity, and adult annual survival at Año Nuevo Island and Southeast Farallon Island. The Trustees relied upon this data and estimates from other alcids, calibrating the parameters subject to the constraint that the population be constant.

#### Rhinoceros Auklet

- *Age of First Breeding*: 4 Years Old
- *Female Offspring per Female*: 0.325
- *Annual Survivorship (Age 1-2+)*: 85%
- *Survivorship (From fledge to one year of age)*: 75%
- *Maximum Age*: 30 Years

The result is that the bird-year multiplier for Rhinoceros Auklets is **5.52**.

This multiplier is then applied to the various mortality events, discounted to 2006.

Spill Event	Estimated Mortality	Discounted Lost Bird-Years
winter 1990-91	59	507
chronic 1993-97	1	8
winter 1997-98	379	2,650
chronic 1998-2001	5	32
2001-2003	149	899
<b>TOTAL</b>	<b>593</b>	<b>4,095</b>

Total discounted lost bird-years for Rhinoceros Auklets: **4,095**

### CREDIT CALCULATION (projected restoration benefits)

These injuries will be addressed by restoration efforts at Año Nuevo Island. The restoration work on Año Nuevo is expected to increase the number of nests on the island. Without the project, the auklet colony would likely decline rapidly due to soil erosion. Thus, the restoration benefits derive from the difference between modest colony growth with the project and total loss of the colony without the project.

For scaling purposes, without the project, the number of nests on the island falls from its current level of 106 to zero over 21 years (losing 5 nests per year). With the project, the colony is maintained and the number of nests increases at 2% per year, from 106 to 134 at the end of the project life. Once the project ceases, there is considerable uncertainty about the persistence of the colony. If the native vegetation cover is not firmly

established, erosion processes may repeat. The Trustees have accounted for uncertainty after the life of the project by assuming a decrease in the number of nests at a rate of 5 nests per year. Thus, the project is assumed to provide some level of benefits through 2045. The table below presents these results.

Year	Nests w/o Project	Nests w/ Project	Gained Nests	Gained Fledges	Gained Bird-Years	Discounted to 2006
2007	106	106	0	0	0	0
2008	100	108	8	5	27	26
2009	95	110	15	10	51	48
2010	90	112	22	15	75	69
2011	85	115	30	19	100	89
2012	80	117	37	24	124	107
2013	75	119	44	29	149	124
2014	70	122	52	34	173	141
2015	65	124	59	38	198	157
2016	60	127	67	43	223	171
2017	55	129	74	48	249	185
2018	50	132	82	53	274	198
2019	45	134	89	58	300	210
2020	40	129	89	58	300	204
2021	35	124	89	58	300	198
2022	30	119	89	58	300	192
2023	25	114	89	58	300	187
2024	20	109	89	58	300	181
2025	15	104	89	58	300	176
2026	10	99	89	58	300	171
2027	5	94	89	58	300	166
2028	0	89	89	58	300	161
2029	0	84	84	55	283	148
2030	0	79	79	52	266	135
		Continues to lose 5 nests per year; reaches 0 in 2045.	Continues thru 2045.	Based on 0.65 fledges per nest.	Based on 5.15 bird-years per fledge (life expectancy of a fledge)	Discounted at 3% per year
<b>Total:</b>						<b>4,299</b>

Under these assumptions, this project compensates for the lost bird-years.

## Appendix M: Sea Otter/Public Education REA Details

### INJURY CALCULATION

Because the otters saved by the restoration action are assumed to be from the same demographic age classes as those impacted by the spills (and thus have the same contribution to future population size), calculating lost otter-years is not necessary. Instead, the Trustees simply counted lost and gained otters, discounted to 2006.

The Trustees estimate that eight sea otters were killed by mystery spills between 1995 and 2002.

<b>Spill Event</b>	<b>Estimated Mortality</b>	<b>Discounted Otter Loss</b>
winter 1995-96	2	2.77
winter 1998-99	2	2.53
winter 2001-02	4	4.64
<b>TOTAL</b>	<b>8</b>	<b>9.9</b>

The total loss is 9.9 sea otters, discounted to 2006.

### CREDIT CALCULATION (projected restoration benefits)

The injuries will be addressed by a public education project intended to reduce the mortality of sea otters that results from certain human actions. Quantifying the decreased level of pollution and the resulting increased survival of sea otters from a public education project involves considerable uncertainty. To evaluate the potential of the project to achieve the necessary compensation, the Trustees instead asked how many otters must be “saved” by the project in order to offset the injury, and whether or not this level of decreased otter mortality was likely to be achieved by the project.

If the project saves two sea otters per year over a six-year period, a total of 10.8 “discounted” otters would be saved, thus compensating for the injury.

<b>Year</b>	<b>Otters Saved</b>	<b>Discounted Otter Gain</b>
winter 2007-08	2	1.94
winter 2008-09	2	1.89
winter 2009-10	2	1.83
winter 2010-11	2	1.78
winter 2011-12	2	1.73
winter 2012-13	2	1.67
<b>TOTAL</b>	<b>12</b>	<b>10.8</b>

Based on Gerber et al (2004), approximately 325 sea otters die each year. 59 of these (18%), and possibly as many as 156 (48%), die from diseases, some of which will be addressed by the project. If the project can reduce this mortality just 4%, the goal of saving two otters per year will be achieved. The Trustees believe this is possible.